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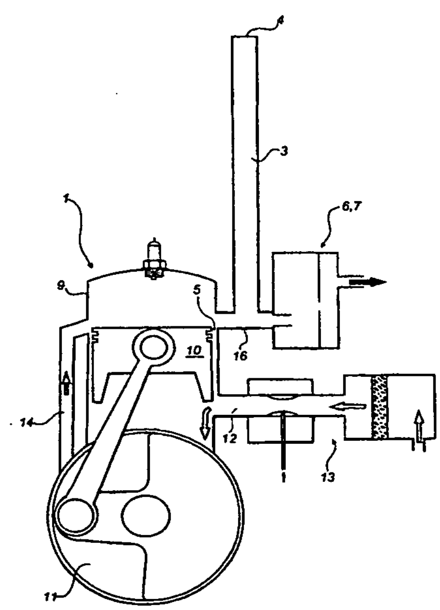
(54) Title: TWO-STROKE INTERNAL COMBUSTION ENGINE



(57) **Abstract:** A two-stroke internal combustion engine (1), mainly intended for a working tool, preferably a chain saw or a trimmer, and provided with a muffler device (2). A pipe (3), which either is straight or bent, and having an adapted or tuned length and a closed outer end (4), is arranged in connection to the engine's exhaust port (5) as well as an outlet (6), which leads the exhaust gases to the surrounding air. By this arrangement of the pipe (3) and the outlet (6) the scavenging losses are reduced and thereby the specific fuel consumption is reduced and cleaner exhaust gases are achieved.

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TWO-STROKE INTERNAL COMBUSTION ENGINE

Technical field

The subject invention relates to an internal combustion engine of two-stroke type, mainly intended for a working tool, preferably a chain saw or a trimmer, and provided with a muffler device.

Background of the invention

For working tools run by internal combustion engines generally two-stroke engines are used, mainly due to their low weight and simple design. Also, the crankcase scavenging enables a lubrication system independent of position, in which the engine is lubricated by oil which is added to the air/fuel mixture scavenged through the crankcase. The all-position lubrication system is necessary e.g. for chain saws, since they are to be used in a lot of different working positions. Two-stroke engines for mopeds and motor-cycles generally have a so called tuned exhaust system. Reflected pressure pulses from the exhaust system will press scavenging gases back into the cylinder so that the engine's scavenging losses are reduced. In total this means that both the power output and fuel consumption can be improved in comparison with a non-tuned exhaust system. However, in order to function well the tuned exhaust system requires large lengths of pipe as well as large cross-section areas in the exhaust duct. Such a muffler for a chain saw would be at least half a meter long and consist of a first conically expanding duct section by approximately 8 degrees, and a second conically narrowing section by approximately 12 degrees. Between these conical parts there should be located a straight part having a diameter, or actually a cross-section area, which is many times larger than the exhaust port. If e.g. the exhaust port would have a diameter of 30 mm then the straight part would have a diameter of approximately 60-100 mm, that is almost 10 times larger cross-section area. Thereafter an absorption muffler should be connected

in order to reach reasonably low sound-levels. As mentioned above such a muffler is based on reflected pressure pulses as well as a low total pressure drop. Regarding working tools it has turned out that such a muffler will be far too large and heavy, even if the pipe system is provided with a lot of curves. This is due to the large cross-section areas. For, a working tool must be very light-weight, compact and handy in order to serve its purpose. Consequently, tuned exhaust systems are normally not used for working tools. Instead they have light-weight and compact mufflers in which the sound mainly is damped by throttling in the muffler. A larger cylinder volume is used to reach the preferable effect. Owing to the fact that there are great differences between the layout of two-stroke engines with tuned exhaust systems and without tuned exhaust systems, it is difficult to transfer experiences from one field to the other.

A well-known problem of two-stroke engines is their relatively high fuel consumption caused by high-scavenging losses, i.e. scavenging gases which flow straight out into the exhaust system. This also results in high emissions, especially of hydrocarbons. As mentioned above, the difficulties to overcome this problem are especially big for two-stroke engines with light-weight and compact mufflers, i.e. with non-tuned exhaust systems. The high emissions of hydrocarbons also results in certain problems when using a muffler with catalytic conversion. For, the very high energy content of the exhaust gases leads to a very high heat generation in the catalytic converter as well as in the surrounding muffler. This high extent of heat generation could mean that the conversion ratio in the catalytic converter must be kept down. Consequently, the high scavenging losses increase the fuel consumption at the same time as they complicate a co-operation with an exhaust catalytic converter.

Purpose of the invention

The purpose of the subject invention is to substantially reduce the above outlined problems for a two-stroke internal combustion engine, provided with a silencing device.

Summary of the invention

The above-mentioned purpose is achieved in a device in accordance with the invention, having the characteristics appearing from the appended claims.

The two-stroke internal combustion engine in accordance with the invention is thus essentially characterized in that a pipe, which is either straight or bent, and having an adapted or tuned length and a closed outer end, is arranged in connection to the exhaust port of the engine, as well as an outlet, which lead the exhaust gases to the surrounding air. When the exhaust port is opened a powerful pressure pulse is created which runs into the pipe and is reflected by its closed outer end. If the pipe is given a correctly tuned length for a given rotational speed, for example maximum power rpm, the reflecting pressure pulse from the pipe will increase the exhaust pressure outside the exhaust port before it will be closed, so that the pressure becomes higher than the pressure inside the cylinder. Thereby further scavenging gases are prevented to flow out and some of the scavenging gases could even be pressed back into the cylinder. Therefore the scavenging losses are reduced and the engine's power can be increased and its specific fuel consumption be reduced.

The exhaust emissions, especially of hydrocarbons, will be reduced substantially, with the result that also the heat strain on an eventual following exhaust catalyser will be reduced, so that its co-operation with the engine will be simplified.

Even if the invention primarily is intended for an engine for a working tool it might as well also be used for other kind of motor applications.

Further characteristics and advantages of the invention will become more apparent from the detailed description of preferred embodiments and with support of the drawing figures.

Brief description of the drawing

The invention will be described in closer detail in the following by way of various embodiments thereof with reference to the accompanying drawing

figures, in which the same numeral references in the different figures denote corresponding parts.

Figure 1 illustrates schematically in cross-section an internal combustion engine of two-stroke type in accordance with the invention. It shows a muffler device that comprises a pipe and an outlet according to the invention. The outlet takes place through a conventional muffler.

Figure 2 shows a cross-sectional view of the upper part of the engine according to figure 1 but equipped with a somewhat different muffler device only consisting of a pipe and an outlet. Those parts of the pipe which are lying above the plane of the paper are shown by dash-dotted lines.

Figure 3 shows a third embodiment of the muffler device, where the outlet takes place through a muffler with catalytic converter.

Description of embodiments

In the schematic figure 1 numeral reference 1 designates an internal combustion engine of two-stroke type. It has a cylinder 9 with a piston 10, a crankcase 11, an inlet 12 with a fuel supply device, such as a carburettor 13, and furthermore scavenging ducts 14 and a spark plug 15. All this is conventional and will therefore not be described in closer detail. An exhaust pipe 16 connects to the engine's exhaust port 5 at its inner end and at its outer end it connects to a muffler 7. What is characteristic is that a pipe 3 with an adapted or tuned length and a closed outer end 4 is arranged in connection to the engine's exhaust port 5. Since the outer end 4 is closed exhaust gases can not flow through the pipe 3. Instead they will flow out through an outlet 6, which is arranged via the conventional muffler 7. The outlet 6 can also contain a catalytic converter 8, which is shown in figure 3, or could be just an outlet into the air without any surrounding muffler, as shown in figure 2. The pipe could be arranged so that it connects directly to the exhaust port 5 without any intermediate part, as shown in the figures 2 and 3. However, there can also be an exhaust pipe 16 or similar, as shown in figure 1. What is essential for the function is that the pipe 3 as well as the outlet 6 are arranged in connection to the engine's exhaust port 5. Hereby a powerful reflected pressure pulse is created in the pipe. For, the pressure wave

that is created when the exhaust port is opened will travel to and fro in the pipe. With an correctly tuned length of the pipe the pressure wave will at a suitable rotational speed turn back to the exhaust port exactly before it is closed and will hold back the outflow and even push back scavenging gases, i.e. air/fuel mixture, into the cylinder. The arrangement can be regarded as a three-legged intersection created in connection to the engine's exhaust port 5, with one branch to the port, one branch out to the pipe 3 and one branch through the outlet 6. The angles between the branches can be varied very much, e.g. the pipe can be located straight out from the port at an angle of 180°, or crosswise, i.e. at an angle of 90°. Consequently, when calculating the length of the pipe also the distance from the exhaust port to the mouth of the pipe must be considered. If this part should have another cross-section area than the pipe, then it has to be calculated as one with the pipe co-operating oscillation pipe. Also the length of the outlet 6 can affect the oscillation somewhat, and this can also be counted as a participant in the total oscillation. The outlet can also consist of several following parts which to some extent will affect the oscillation in the pipe.

The outlet 6 shall have a smaller cross-section area than the pipe 3. Preferably 0,1 – 0,7 times the cross-section area of the pipe. This is important in order to achieve a satisfactory pressure pulse into the pipe 3. The outlet can be arranged as a cavity or as a tube, which connects to the air or to a muffler. The pipe 3 will change the conditions of the flow so that a cavity or a tube with a smaller cross-section area can be used without increasing the pressure fall over the muffler device. One can say that the pipe has a buffer function that on the one hand changes the exhaust flow over the time period and on the other hand decreases the outflow of the scavenging gases. It is advantageous if the smallest cross-section area in the outlet 6 is located early in the outlet. Preferably the three throttlings in the outlet 6 as shown in figure 1 should be of approximately the same size. It is also important for the function that the outlet 6 is located adjacent the exhaust port 5. Preferably the outlet is located at a distance from the exhaust port that is less than half the length of the pipe 3, and preferably less than a quarter of its length. By a location close to the exhaust port there is less risk that the returning pressure pulse will be soft down before it reaches the exhaust port.

It is also an advantage that any exhaust flow in the pipe will be reduced to a shorter part of the pipe closest to the exhaust port.

Preferably the pipe has an essentially constant cross-section area along its entire length. However, it could also have some local change of the area, for example a conical section, over its length, or have a slightly conical section over its entire length. It is also conceivable that the pipe is provided with a volume connected to its outer end, and that the length of the pipe and the size of the volume are adapted to obtain the correct tuning. Preferably the cross-section area of the pipe is of the same order of size as the area of the exhaust port, i.e. 0,3 – 3,0 times the cross- section area of the exhaust port. The area of the pipe could thus be varied rather widely and its cross-section area has importance for how strong the returning pressure pulse will be. A very small cross-section area would give a negligible effect while the effect would increase with an increasing area up to a maximum. It is thus not an advantage to have a very large cross-section area and the pipe differs in two completely determining ways from a so called tuned pipe in a tuned exhaust system. In the tuned exhaust system there is a flow through the pipe and this pipe has a very large cross-section area to enable a powerful reflecting pressure pulse from the outer end of the pipe even though this is provided with a through-flow aperture. Obviously, the size of the through-flow aperture may not be so small that the muffler provides an unacceptably great through-flow resistance. It means thus that the pipe 3 essentially has no through-flow and has considerably smaller cross-section areas than a pipe in a tuned exhaust system has. The design and way of function are thus very different.

As a rule it is desirable to adapt the length of the pipe 3 so that a considerable fuel saving effect is achieved at max power. This is valid particularly for a chain saw or similar tool, which during a great deal of its running time is running at max power speed. For such a high-speed engine also the pipe becomes shorter than for a more low-speed engine. For, the time period between opening and closing of the exhaust port is shorter at a higher rotational speed. In such a high-speed engine the pipe will be approximately 4-5 decimetres long and will have a cross-section area approximately as large as the cross-section area of the exhaust port. It means that the total volume in the pipe 3 is

relatively limited and the pipe can therefore be rolled up, so that it requires quite a limited space, e.g. the pipe according to figure 1 could be rolled up to a coil around the exhaust pipe 16. This coil could also be placed inside the muffler 7, e.g. by drawing this more close to the engine's cylinder than what is shown in the figure. The coil could either be rolled up into one plane or could have a pitch, such as a thread, which is shown in the figures 2 and 3. The pitch is here somewhat exaggerated for the sake of clarity. The determining fact is that the pipe is given the correct length.

The test results obtained with the invention are very interesting. Since the outflow of scavenging gases were reduced also the fuel consumption and the exhaust emission were reduced at the same time as the output of the engine was increased. This is valid for the speed range, which the length of the pipe is tuned for, e.g. the speed range of maximum power of the engine. Test runs with such an engine have thus shown that the specific fuel consumption could be reduced by approximately 10 % and the engine output could be increased by approximately 10 %, while the emissions of hydrocarbons were approximately halved at the same time as the emissions of nitrogen oxides were reduced considerably.

However, besides that a substantial reduction of the sound level of the engine is achieved. The pipe 3 simply contributes considerably to silencing of noise of the engine. The volume in the pipe 3 serves as a buffer volume, which is advantageous considering silencing. This can be used in many different ways. One way is to reduce the sound level of the engine considerably by maintaining the same muffler 7 as that of a corresponding engine without pipe 3. Another way is to reduce the volume of the muffler 7 and still achieve a sound level that is as high or lower than that of a corresponding engine with a conventional muffler. An example of such a solution is shown in figure 3. The muffler 7 is there given a very limited volume. Figure 2 shows the most far-reaching example where the muffler 7 is missing completely, so that the pipe 3 alone serves as a muffler device 2. It is important to note that there is essentially no flow in the pipe 3, since the outlet 6 is located far up-stream close to the exhaust port 5. It means that the pipe 3 becomes considerably cooler than the outlet 6 or the muffler 7. By winding the pipe 3 around the hot parts it will thus protect from

contact with these. For the sake of clarity the pipe 3 is shown with very few winding turns in the figures 2 and 3.

Consequently, by means of the pipe 3 the emissions of particularly unburned hydrocarbons can be reduced considerably. This preferably occurs at maximum power speed of the engine. Thereby the heat strain on a catalytic converter element 8 and on the muffler 7 into which the element is mounted will be reduced considerably. It means that a more effective conversion can be utilized without a too high temperature. The invention thus improves the work conditions for an exhaust catalyser. A catalytic converter element could also be placed in the pipe 3, so that it alone or in combination with at least one catalytic converter element in the outlet 6 is cleaning the exhaust emissions.

Also, due to the returning pressure pulses from the pipe 3 a stirring effect is created in the exhaust pipe 16. This is valuable for all two-stroke engines but particularly advantageous if the engine 1 is of so called air-head type. In such an engine the scavenging duct 14 will be filled with fresh air, which at first is scavenged into the combustion chamber and then forces the exhaust gases ahead out through the exhaust port. It means that into the exhaust pipe 16 will come: first exhaust gases, then air and thereafter air/fuel mixture which is lost out through the exhaust port. The invention could thus, on the one hand reduce the loss of air/fuel mixture out through the exhaust port, but also on the other hand create a more even distribution of the air/fuel mixture and the air in the exhaust gases in the muffler, so that a following catalyser could function better.

Furthermore, the fact is that the pipe is cooling down the exhaust gases somewhat. It means that the exhaust mixture becomes cooler. This is particularly advantageous in connection with an air-head-engine, since both the demand for exhaust homogenisation as well as cooler and leaner exhaust gases are greater for such an engine than for a conventional two-stroke engine. For, the increased surplus of oxygen in the exhaust gases leads to an increased risk of after-oxidation in the muffler for such an engine than for a conventional two-stroke engine. The risk is particularly great if a catalyser is used for the whole or a part of the exhaust flow in the muffler. An after-oxidation in the muffler leads to that

all combustible exhaust components will be oxidized so that an unacceptable heat generation takes place.

As mentioned above the pipe can be tuned for a suitable rotational speed of the engine, usually the maximum power speed of the engine. However, in combination with an air-head-engine it could also be interesting to tune against a lower rotational speed. For, the purpose of the air-head system as such is to reduce the engine's emissions and its tuning is preferably carried out so that the engine's emissions will be reduced especially much at the maximum power speed of the engine. A tuning in order to achieve maximum reduction of the emissions at a considerably lower rotational speed would lead to deterioration of the engine performance. In this regard the pipe is more flexible and in combination with air-head it could then be tuned against a lower rotational speed than the engine's maximum power rotational speed. This means that the engine will get a considerably reduced level of emissions at this lower rotational speed. E.g. the emissions could be more than halved at a speed of 100 rotations per second by the aid of a pipe that is tuned for this engine speed in an air-head-engine with a maximum power speed of approximately 160 rps. At the higher rotational speed the pipe will have a very small effect on the emission degree, perhaps even a negative effect, since its pressure pulse will occur too late, but at the lower rotational speed it will thus have a significant effect. Accordingly, hereby the engine's characteristics within a wider range of rotational speeds will be improved in that the air-head technology gives an improvement that is greatest at the higher rotational speed while the pipe will improve it further at the lower speed. Obviously, both techniques will provide improvements also beside the tuned rotational speed, but to a decreasing degree. In this way the engine could thus cover a wider speed range regarding exhaust emissions.

However, it would also be possible to utilize this effect from a kind of co-ordinating point of view. A chainsaw engine of air-head type, e.g. tuned for the higher speed 160 rps, could be provided with a pipe tuned e.g. for 100 rps for use as a blower engine running at a very constant lower rotational speed. Hereby a very low degree of exhaust emissions can be achieved at this lower rotational speed even though the engine in other respects is not fully tuned for it. Preferably

the length of the pipe in this case is tuned for a rotational speed that is essentially lower than the maximum power speed of the engine, i.e. 50-90 % of this, and preferably 55-75 % of this.

It must be pointed out that in most portable working tools it is extremely difficult or almost impossible to get space for a perhaps 40-70 cm long pipe. In particular, it seems most easy in a blower.

CLAIMS

1. An internal combustion engine (1) of two-stroke type, mainly intended for a working tool, preferably a chain saw or a trimmer, and provided with a muffler device (2), c h a r a c t e r i z e d in that a pipe (3), which is either straight or bent and having an adapted or tuned length and a closed outer end (4), is arranged in connection to the engine's exhaust port (5), as well as an outlet (6), which leads the exhaust gases to the surrounding air.

2. An internal combustion engine (1) according to claim 1, c h a r a c t e r i z e d in that the outlet (6) is located at a distance from the exhaust port that is less than half the length of the pipe (3) and preferably less than a quarter of its length.

3. An internal combustion engine (1) according to claim 1 or 2, c h a r a c t e r i z e d in that the outlet (6) is arranged in form of a muffler (7).

4. An internal combustion engine (1) according to any one of the preceding claims, c h a r a c t e r i z e d in that the pipe has an essentially constant cross-section area along its entire length.

5. An internal combustion engine (1) according to any one of the preceding claims, c h a r a c t e r i z e d in that the cross-section area of the pipe (3) is of the same order of size as the area of the exhaust port, i.e. 0,3 – 3,0 times the cross-section area of the exhaust port.

6. An internal combustion engine (1) according to any one of the preceding claims, c h a r a c t e r i z e d in that the outlet (6) has a smaller smallest cross-section area than the pipe (3), i.e. 0,1 – 0,7 times the cross-section area of the pipe.

7. An internal combustion engine (1) according to any one of the preceding claims, c h a r a c t e r i z e d in that the pipe (3) is arranged in form of a coil, which extends around the outlet (6) or the muffler (7).

8. An internal combustion engine (1) according to any one of the preceding claims, c h a r a c t e r i z e d in that the pipe is arranged in form of a coil and is placed inside an adapted muffler (7).

9. An internal combustion engine (1) according to any one of the preceding claims, c h a r a c t e r i z e d in that the outlet (6) or the muffler (7) is provided with at least one catalytic converter element (8).

10. An internal combustion engine (1) according to any one of the preceding claims, c h a r a c t e r i z e d in that the engine is of a so called air-head type.

11. An internal combustion engine (1) according to claim 10, c h a r a c – t e r i z e d in that the length of the pipe is tuned for a rotational speed that is essentially lower than the maximum speed of the engine, i.e. 50-90 % of this, and preferably 55-75 % of this.

1/2

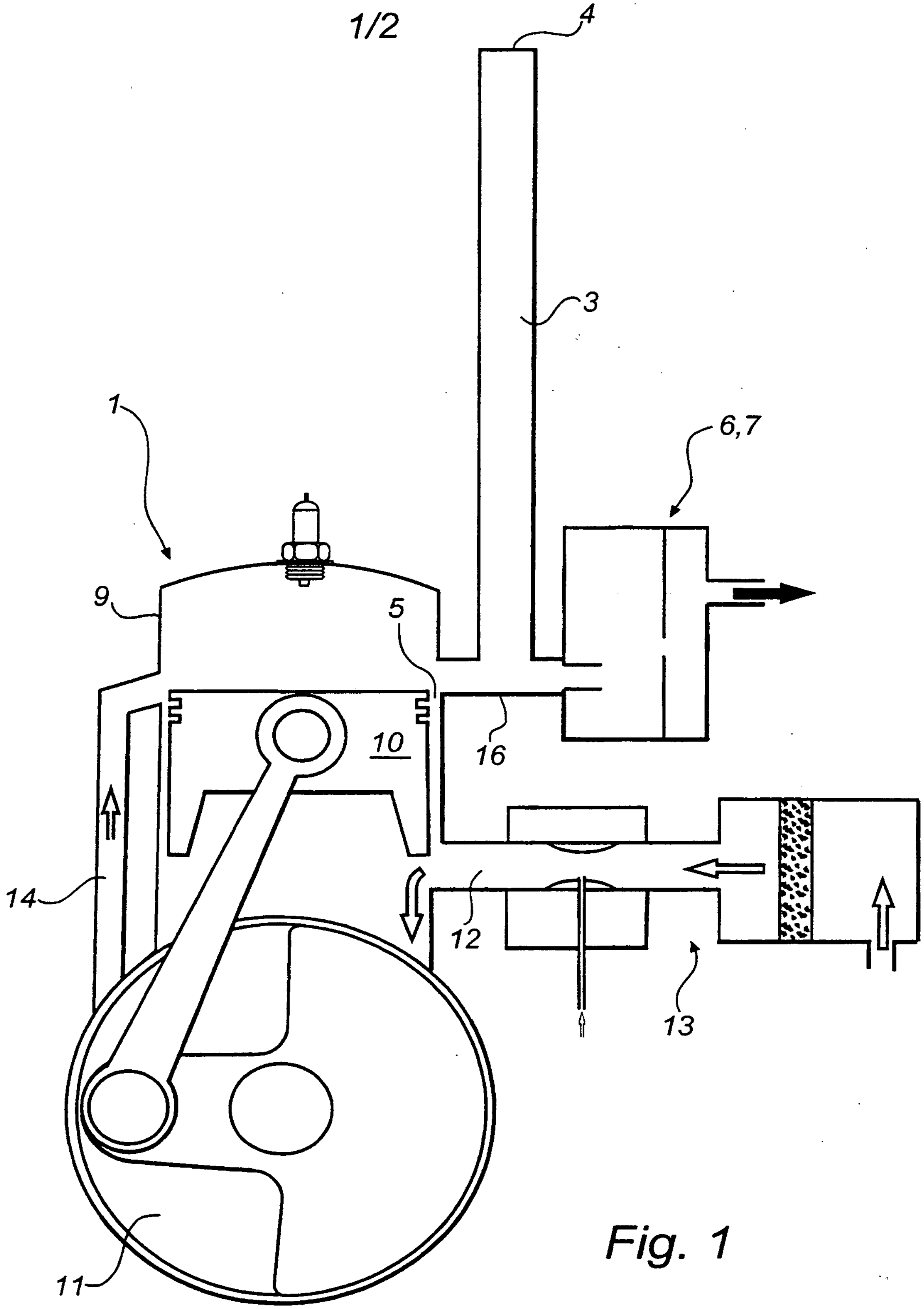

Fig. 1

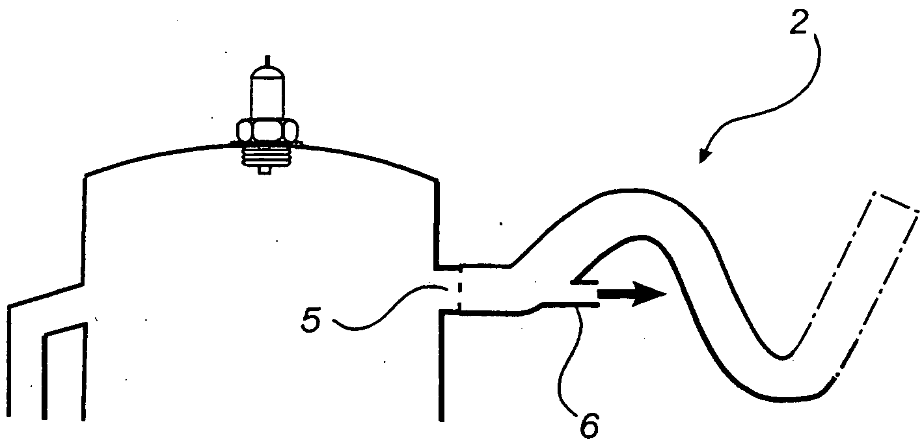

Fig. 2

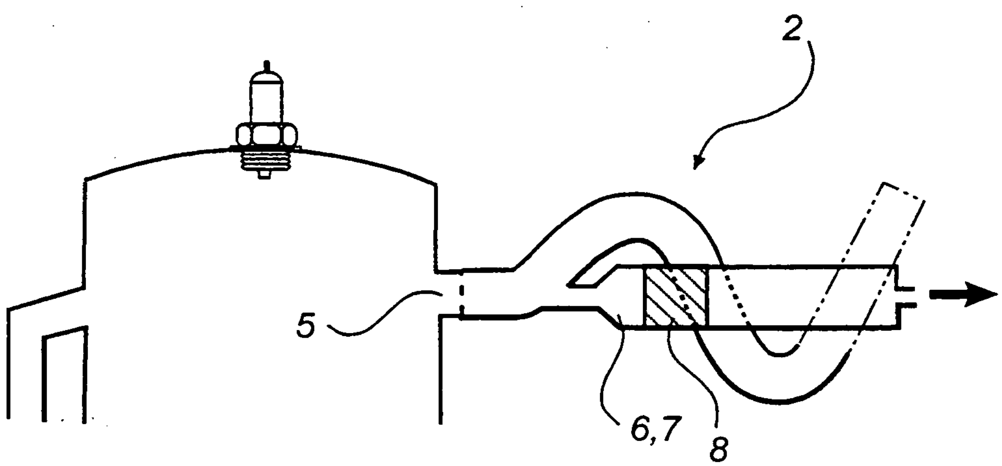

Fig. 3

INTERNATIONAL SEARCH REPORT

International application No.
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A. CLASSIFICATION OF SUBJECT MATTER

IPC7: F01N 1/02, F02B 25/20, F02B 63/02
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: F01N, F02B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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X	WO 9717531 A1 (ACTS LIMITED), 15 May 1997 (15.05.97), figures 1,2, abstract --	1-10
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[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
1 December 2000	08 -12- 2000
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INTERNATIONAL SEARCH REPORT

International application No.
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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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Information on patent family members

02/11/00

International application No.
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